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VISUAL DETECTION OF PINPOINT TARGETS

by

G. Molokanov

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By: G. Molokanov

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А а	*А а*	A, a	Р р	*Р р*	R, r
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В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
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И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

GRAPHICS DISCLAIMER

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VISUAL DETECTION OF PINPOINT TARGETS [1].

FOOTNOTE.
According to materials of the foreign press.
END FOOTNOTE.

G. Molokanov

In spite of the successes, achieved in the development of navigation aids, their possibilities, in the opinion of the number of foreign specialists, these do not completely correspond to contemporary requirements, especially during the flights at low and maximally low altitudes. Therefore increasingly more persistently is studied a question as to what degree during the solution of the basic problems of air navigation it is possible to rely on the abilities of man.

Many foreign specialists think, that visual orientation often can prove to be only means of detection and identification of pinpoint targets. Not randomly abroad serious value is given to the resolution of the problem of the visual detection of ground-based and waterborne targets.

Even in period of Second World War group of scientific workers of U. S. Navy conducted research, dedicated to search for waterborne targets. Some results of these works were published in the journal of the American society of operations research by the name "Theory of search". After this, to the visual search for objects were devoted

many theoretical and experimental studies, whose results repeatedly were discussed at the special symposia.

In English journal of institute of navigation No. 3 of 1965 was published the article of Hip "Visual factors in the air navigation". In it is given the survey of the number of investigations on the visual and television search for ground-based objects and is made the attempt to estimate the effect of many factors on the possibility of visual detection and identification of pinpoint targets.

Short presentation of some questions, illuminated in this article, is given below. Naturally, not all are solved sufficiently fully and it is necessary to relate critically to the conclusions of the authors. However, acquaintance with similar investigations can prove to be useful. Thus, let us examine the content of the mentioned article.

Possibility of visual target detection, located on uniform background, depends on sizes of this object and its contrast. By contrast K is understood the ratio of difference ΔB between the visible brightnesses of object and background to the visible brightness of background B.

$$K = 1.0\frac{\Delta B}{B}. \qquad (1)$$

Minimum value $K_{мин} = \varepsilon$, with which eye distinguishes object, is called threshhold of contrast sensitivity of eye.

Bringing into question results, obtained earlier under laboratory conditions for different illumination, when objects were detected at threshold of contrast sensitivity $\varepsilon = 0.3\%$. Hip gives dependence between angular dimensions of object and its contrast, with which object can be discovered under actual conditions. For the target detection, on the affirmation of Hip, the contrast must be approximately 10 times higher than obtained in the laboratory experiment. For comparatively large objects, whose angular dimensions exceed 1°, ε little depend on the sizes of object and are approximately 3%. However, contrast of small size objects with the visible sizes of order of one angular minutes must compose already approximately 180%.

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Important characteristic of small size objects (less than 10'), determining possibility of their visual detection, is product of threshold of contrast to area of object or to square of its angular dimension α. For the pinpoint targets it remains constant value, equal to $\alpha^2 \cdot \varepsilon \approx 180$. Consequently, if the visible angular dimensions of the object in all is 0.5', then its contrast, with which the object is detected, must be $\varepsilon = \frac{180}{0.25} = 720\%$, and if object is ten times more, i.e., α=5', then its contrast can be one hundred times less (about 7%).

In meteorology abroad during determination of horizontal visibility is according to solution, accepted in 1958. With

international board for instruments and methods of observations, one should take ε=5%. If the image of object is projected to the most sensitive part of the eye - fovea of yellow spot, whose angular dimensions are near 1°6, then ε=1.6% (foveate line of sight). On the use of quantitative criteria rests the lobe theory of the foveate target detection. In accordance with this theory and number of the experimental works, which were being carried out in 1962, were determined the boundaries of that region (lobe/lug), in limits of which the ground-based object of the specific size and specific dimension and contrast can be discovered at first glance. The form of this region and its relative sizes, expressed in the portions of the meteorological visibility L, are shown in Fig. 1. The range of detection D is maximum, in proportion to the distance of object from this direction it considerably is reduced along the foveate ray, since the effectiveness of peripheral vision substantially decreases.

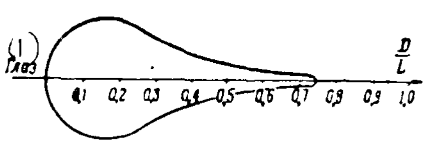

Fig. 1. Region (lobe/lug), in limits of which at first glance can be discovered ground-based object of specific sizes/dimensions and contrast.

Key (1). Eyes.

Aforesaid relates to most favorable conditions for observation, when object is located against uniform background. Under the actual conditions the possibility of the target detection strongly depends on such factors as flight speed, error, with which is known the position of object, visibility, flight altitude, accuracy of air navigation, etc. The effect of different factors on the range of detection of the object, which has the dimensions of 1.8×3.6 m, can be estimated with the aid of the empirical formula, which in the accepted dimensionality takes the form:

$$D \approx 0.1\sqrt{H\sqrt{L}}\, e^{-0.12\frac{V}{100}+0.78\left(1-\frac{R}{185}\right)^{3}}. \quad (2)$$

where D - detection range in km;

H - flight altitude m;

L - visibility in k;

V - flight speed in km/h;

R - radius of the field of search for object m.

Turning to itself attention of essential contraction of detection range, if position of object is not accurately known $(R \neq 0)$ and is necessary its search in limits of zone with radius R, in comparison with case, when position of pinpoint target (of type of motor vehicle) is known accurately (R=0).

Calculated according to formula data for some conditions of range of detection of object with size of 1.8×3.6 m are cited in Table 1.

Table 1.

H м	V км час	$R=0$, $L=10$ км	$R=0$, $L=20$ км	$R=370$ м, $L=10$ км	$R=370$ м, $L=20$ км
100	400	2.6	3.1	0.54	0.65
	800	1.6	1.9	0.33	0.40
	1200	1.0	1.2	0.20	0.25
300	400	4.5	5.4	0.95	1.1
	800	2.8	3.4	0.59	0.7
	1200	1.7	2.1	0.36	0.44
500	400	5.8	7.1	1.2	1.5
	800	3.6	4.4	0.76	0.92
	1200	2.2	2.7	0.47	0.57
1000	400	8.3	10.0	1.8	2.1
	800	5.2	6.2	1.1	1.3
	1200	3.2	3.8	0.67	0.81

Key: (1). km/h.

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It is evident from table that with good visibility its improvement almost does not affect detection range. Hip does not indicate range of the conditions, for which formula (2) is obtained; therefore one should relate carefully and check the results of calculations, how actually is reduced the range of detection of small size object if necessary for its search in the limits even of low region of change of hundred meters. Obviously, this depends on stage of masking of object in the area of arrangement. For the evaluation of the decrease of the range of detection of pinpoint target it is possible to give such considerations. If we are entrusted with calculated data, then in the accurately known position of object and visibility of 10 km at the speed of 800 km/h and at flight altitude of

1000 m it must be discovered at a distance of 5.2 km, whereas if necessary for the search for object at a radius only of 370 m the medium range of its detection is only 1.1 km. At the flight speed of 800 km/h (222 m/s) distance, equal to difference of these ranges of detection, aircraft will fly for the time of (5200-1100)/222=19 s. This time, apparently, is spent in order to find object in the limits of the zone with a radius of 370 m. It is interesting to compare the visible angular dimensions of this field of search of the angular dimensions of the fovea of the eye of man, since foreign specialists consider that detecting and identifing objects is precisely by this presence, i.e. by the foveate part of the view with the angle of visual cone 1°.6 (Fig. 2a).

In Fig. 2b is shown as 19 s approach of aircraft with the object, increases seen angular dimensions of field of search (from ellipse 1 to ellipse 2) and simultaneously decreases (from circle 1 to circle 2) the size of the region, included in foveate ray. This fact in all probability leads to the essential contraction of the detection range.

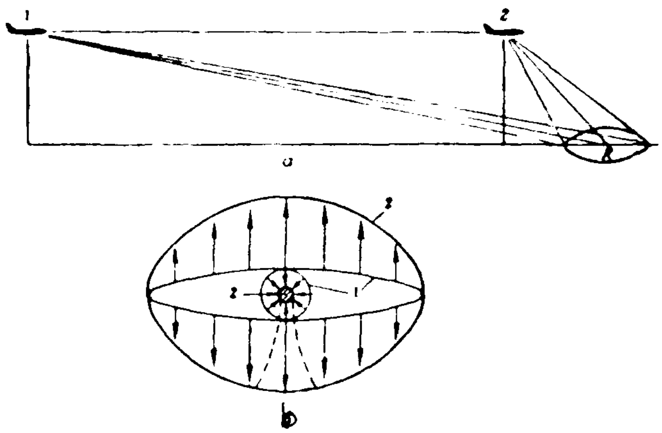

Fig. 2. a) angular dimensions of field of search and fovea of eye; b) increase in those seen angular dimensions of field of search.

In Fig. 3 on the basis of theoretical calculations is shown, how available time of search for object in limit of zone of radius R affects probability of its detection, when position of object is not accurately known. The sizes of the field of search for object are expressed in angular units (in degrees).

During calculation of curves they proceeded from the fact that probability of target detection proportional to square of diameter of field of search, examined by series of cursory views, moved from one section to another in 1.5 s. An increase in the angular dimensions of field of search with the short time of observation is accompanied by the sharp contraction of the probability of the target detection.

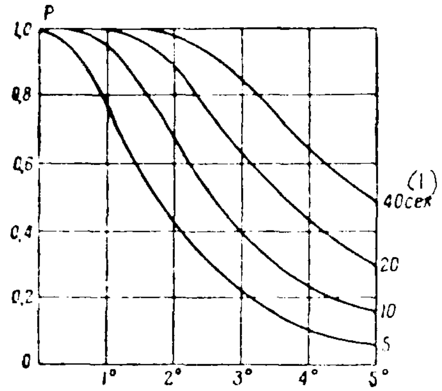

Fig. 3. Effect of available time of search for object on probability of its detection.

Key: (1). s.

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According to data of studies, which were being carried out in Farnborough, it was established that probability of target detection depends substantially on accuracy of air navigation.

It is evident from Fig. 4 that probability of target detection substantially is reduced during deviation of aircraft from assigned route.

Thus, if with accuracy of enroute flight, characterized by average quadratic lateral deviation, equal to $\sigma_{БУ} = 300$ m, probability of detection of pinpoint target composes 0.8, then decreases approximately doubly with $\sigma_{БУ} = 1$ km. It was established that the observer, free from the responsibility of aircraft handling, had considerably better possibilities on the target detection in the course of search.

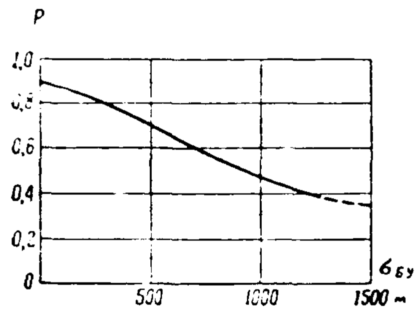

Fig. 4. Effect of deviation of aircraft from assigned route on probability of target detection.

As that most being adequate for visual orientation abroad is considered map of scale 1:250000, probability of identification of reference points on which in flight above territory of South England, southern and northern areas of FRG with a velocity of 550-830 km/h depending on arrangement of reference points in broken ground or linear reference point composes 0.71-0.93.

In Table 2 are given the medium detection ranges, the root-mean-square deviation of this value and the percentage of the detection of different reference points, observed visually, also, with the aid of the television equipment for the scale of flight map 1:250000.

During visual orientation of that predominating factor of search also is acknowledged. The reliability of orientation, characterized by the probability of the detection of reference points, significantly grow during the precision determination of their location and is

sufficient frequent correction of navigation aid.

In the opinion of American specialists, if during low-altitude flights previous reference point was discovered and identified, then probability of detection of subsequent reference point is very high. But if the previous reference point is passed, then the probability of the detection of the following sharply falls (approximately to 0.5). Therefore in the article is emphasized the importance of mastery of the procedure of the visual orientation, having high value generally and those during the low-altitude flights.

Table 2.

(a) Ориентиры	(b) Визуально			(c) С помощью телевизионной установки		
	D км	σ_D км	(d) % обнаружения	D км	σ_D км	(d) % обнаружения
(1) Аэродромы, леса, озера, холмы	5,5	1,7	100	4,1	1,8	89
(2) Города и населенные пункты	5,3	1,7	82	2,7	0,9	82
(3) Мосты через реки	5,8	1,5	100	3,1	0,7	93
(4) Ж.-д. и шоссейные мосты	3,7	1,4	90	2,4	1,0	89
(5) Ж.-д. узлы, тоннели и т. д.	5,6	1,4	100	2,7	0,9	87
(6) Дорожные объекты (узлы, перекрестки и т. д.)	4,7	2,2	78	2,5	1,0	91

Key: (a). Reference points. (b). Visually. (c). With the aid of the television equipment. (d). detection. (1). Airfields, forest, lake, hill. (2). Cities and populated areas. (3). Bridges across rivers. (4). ... and highway bridges. (5). ... units, tunnels, etc. (6). Road objects (units, crossings, etc.).

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